

THE UNIVERSITY OF MANITOBA

The crustacean zooplankton communities of three
prairie lakes subject to varying degrees of anoxia

by

Alexander George Salki

A Thesis

Submitted to the Faculty of Graduate Studies
in partial fulfillment of the requirements for the degree
of Master of Science

Department of Zoology
Winnipeg, Manitoba

June 1981

THE CRUSTACEAN ZOOPLANKTON COMMUNITIES OF THREE
PRAIRIE LAKES SUBJECT TO VARYING DEGREES OF ANOXIA

BY

ALEXANDER GEORGE SALKI

A thesis submitted to the Faculty of Graduate Studies of
the University of Manitoba in partial fulfillment of the requirements
of the degree of

MASTER OF SCIENCE

© 1981

Permission has been granted to the LIBRARY OF THE UNIVER-
SITY OF MANITOBA to lend or sell copies of this thesis, to
the NATIONAL LIBRARY OF CANADA to microfilm this
thesis and to lend or sell copies of the film, and UNIVERSITY
MICROFILMS to publish an abstract of this thesis.

The author reserves other publication rights, and neither the
thesis nor extensive extracts from it may be printed or other-
wise reproduced without the author's written permission.



ABSTRACT

The crustacean zooplankton communities in three small prairie lakes subject to varying degrees of anoxia were studied for 14 months from February 1976 to April 1977. Ten or twelve samples were collected with a tube in both the deep and shallow zones of each lake once weekly during summer, biweekly in spring and fall and monthly during winter.

Local terrain was important to lake trophic and stratification. Physical and chemical observations indicated that shallow hypertrophic Lake 885 periodically stratified, exhibited winter and summer anoxia and had extreme nutrient and algal biomass levels. Shallow, meso-eutrophic Lake 255 was holomictic, displayed winter anoxia, and had lowest nutrient and phytoplankton amounts. Deeper, eutrophic Lake 019, stratified through summer, was not completely exhausted of oxygen and contained intermediate nutrient and algal concentrations. Dense populations of planktivorous fish Pimephales promelas and Culaea inconstans occurred in Lake 019 while Salmo gairdneri were stocked in Lakes 255 and 885.

Zooplankton community abundance and biomass, ranging on a mean annual basis from 124.7 to 289.9 ind L⁻¹ and 1.9 to 10.3 mg wet weight L⁻¹ respectively were governed by lake productivity and morphometry. Biomass in Lake 019 was also influenced by intense planktivory. A total of 25 species were identified, of which 10, Cyclops bicuspidatus thomasi, Cyclops vernalis, Eucyclops agilis, Macrocyclops albidus, Diaptomus siciloides, Diaptomus leptopus, Daphnia schoedleri, Daphnia rosea, Daphnia parvula and Bosmina longirostris were common to all three lakes. The number of species, highest in Lake 255 with 21 and lowest in Lake 885 with 15, was inversely related to trophic. More eulittoral species in Lake 255 were associated with extensive macrophyte development. Numerically, cyclopoids were most

important in Lakes 885 and 255 while calanoids and cladocerans were most abundant in Lake 019, these trends being related to the frequency and severity of anoxia. Observed differences in the horizontal distribution of community and species abundance were associated with macrophytes, fish predation and morphology.

Seasonal community development in Lake 019 was basically monacmic with a mid summer pulse. Although diacmic patterns were observed in both Lake 885 and 255, in the former lake, spring densities were triple those of fall, the two pulses separated by a strong depression in late August. Lake 255 exhibited more equitable spring and fall pulses and a mid summer minimum. Highest community abundance during winter occurred in Lake 019. These variations were related to lake trophy, temperature, dissolved oxygen, nutrients, phytoplankton and predation.

Significant differences were observed in the seasonal dynamics of C. b. thomasi, D. siciloides and D. schoedleri. Instar analysis revealed spring emergence of C. b. thomasi from winter diapause only in Lakes 885 and 255. In Lake 019, C. b. thomasi survived through the winter carrying on reproduction. No evidence for summer diapause of this species was found in all three lakes. Spring C. b. thomasi densities were related to the severity of oxygen depletion during the preceding winter and the intensity of invertebrate predation. Summer anoxia did not affect C. b. thomasi copepodids but was apparently fatal to nauplii.

D. schoedleri's presence only in Lakes 885 and 255 reflected reduced planktivory in winterkilled lakes. Delayed seasonal development of D. schoedleri in Lake 885 suggested possible predation by abundant C. b. thomasi. High variation in abundance and polycyclic ehippial production by D. schoedleri in Lake 885 reflected the omnipresent threat of Cyanophyte bloom

collapse. Summer anoxia severely impacted all stages of D. schoedleri.

While large quantities of resting eggs were produced by D. siciloides in winterkilled Lake 255, considerably fewer eggs were carried by females surviving winter in oxygenated Lake 019.

Relatively small differences in lake trophy and morphology appeared to effect considerable differences in oxygen conditions and seasonal crustacean plankton community composition and dynamics.

DEDICATED TO MY CHILDREN

MATTHEW
AND
KERRI

ACKNOWLEDGEMENTS

The author is most sincerely grateful for the patience, guidance and support genuinely extended by two gentlemen, Drs. F. J. Ward and K. Patalas. Their keen interest and invaluable advice provided encouragement and inspiration throughout this learning experience. I also wish to thank Dr. J. Eales for his assistance during the sabbatical of Dr. Ward.

Without the help of Mr. G. Curry, difficult winter sampling would not have proceeded as smoothly. The co-operation and comradary of V. Srisuwantach, P. Tavarutmaneeegal and J. Boonsom, visiting from Thailand, enriched and enlightened field and laboratory activities. The participation of Dr. J. Mathias during a macrophyte vegetation survey was greatly appreciated. The efforts of Drs. J. Barica and B. Ayles, J. Lark, J. Gibson and C. Eccles insured a well organized Erickson field camp where many enjoyable moments were spent.

Other members of the Freshwater Institute also deserve recognition and thanks. I. Davies provided a statistical program to evaluate population estimates. H. Kling kindly offered her unpublished data of algal biomass. D. Laroque and C. Vitt perservered to type the large tables and original text. L. Taite, D. Taite and L. Blouw prepared final versions of many figures. And to numerous colleagues who sacrificed coffee and lunch periods to listen, criticize and clarify my ideas, I hope to repay the thoughtfulness.

Finally, I am deeply indebted to my children, family and friends who willingly offered their love and understanding so that I might accomplish this task.

TABLE OF CONTENTS

	<u>Page</u>
ABSTRACT	ii
ACKNOWLEDGEMENTS	v
LIST OF TABLES	viii
LIST OF FIGURES.	ix
LIST OF APPENDICES	xiv
INTRODUCTION	1
THE LAKES	3
METHODS	14
Field Work	14
Laboratory Analysis of Zooplankton Samples	19
RESULTS.	25
Physical and Chemical Measurements	25
A. Water Temperature Secchi Disc Visibility, Ice and Snow Depth.	25
B. Dissolved oxygen, Water Chemistry and Phytoplankton	36
Lake 019 Fish Population Estimates	47
Zooplankton	47
A. Precision of Community and Population Estimates	47
B. Annual Mean Abundance and Biomass of Zooplankton in Lakes 019, 255 and 885	50
Total Lake Plankton	50
1. Total community	52
2. Individual species	53
3. Taxonomic groups	56
Deep and Shallow Zone Plankton.	56
1. Total community.	59
2. Taxonomic groups	59
3. Individual species	59
C. Seasonal Crustacean Community Dynamics in Lakes 019, 255 and 885	63
Total Lake Zooplankton Community.	63
Deep and Shallow Zone Zooplankton Community	67
Individual Species.	70
1. Seasonal occurrence.	70
2. Seasonal dynamics of the core species.	74

Table of Contents (continued)

	<u>Page</u>
Lake 885	74
Lake 255	95
Lake 019	129
Variation of Animal Size and Fecundity	146
DISCUSSION	156
Morphological and Limnological Variations	156
Annual Community Abundance, Biomass and Species Composition	166
Seasonal Dynamics of Crustacean Zooplankton Communities. .	174
Selected Seasonal Aspects of Major Species	182
SUMMARY.	186
LITERATURE CITED	188

LIST OF TABLES

<u>Table</u>	<u>Page</u>
1. Morphometric parameters of Lakes 019, 255 and 885 (1976-1977)	13
2. Vertical profiles of total dissolved phosphorus (TDP) and total dissolved nitrogen (TDN) ($\mu\text{g L}^{-1}$), dissolved organic carbon (DOC) and dissolved oxygen (DO) (mg L^{-1}) in Lakes 019, 255 and 885 in early August 1976 (after Srisuwantach 1978).	41
3. Average water column nutrient concentrations, gross and net primary production and respiration ($\text{mg C m}^{-2} \text{ day}^{-1}$), and phytoplankton species percent composition in Lakes 019, 255 and 885 during July-August 1976 (modified after Srisuwantach 1978).	42
4. Estimates of the relative abundance of <u>Pimephales promelas</u> and <u>Culaea inconstans</u> in Lake 019 during 1976-1977.	48
5. 95% confidence intervals of community and population estimates of zooplankton (ind L^{-1}) in Lakes 019, 255 and 885.	49
6. Annual mean density (ind L^{-1}), biomass ($\text{mg wet weight L}^{-1}$) and percent composition (%) of crustacean zooplankton species in Lakes 019, 255 and 885, April 1976-April 1977. Groupings reflect species common to all or pairs of lakes. Lake totals exclude harpacticoid nauplii	51
7. Shallow to deep zone ratios of mean annual species density and biomass in Lakes 019, 255 and 885, April 1976 - April 1977	62
8. Mature female to male sex ratios of crustacean zooplankton species in Lake 019, 255 and 885, February 1976 - April 1977.	84
9. Comparison of crustacean abundance in the Erickson study lakes during summer 1976 with several Canadian and Polish lakes	164

LIST OF FIGURES

<u>Figure</u>	<u>Page</u>
1. The location of Lakes 019, 255 and 885 in the Erickson - Elphinstone, Manitoba study area	4
2. Bathymetric maps of lakes showing the distribution of shallow (S) and deep (D) zone sampling stations each with a pair of subsampling sites (O and ● or □ and ■). Subsamples from similarly designated sites within each zone combined, resulting in two composite samples from each zone. Extent of emergent macrophytes and border-line of trees and cultivated fields---- also indicated. Trees, farm buildings and roadways approximately to scale.	6
2a Lake 019	8
2b Lake 225	10
2c Lake 885	10
3. Flexible tube sampler used to collect zooplankton samples. Modified after Pennak (1962)	16
4. Water temperatures in Lakes 019, 255 and 885, February 1976 to April 1977. Upper panels: Depth-time distribution of deep zone isotherms (2°C intervals except 1°C under ice). Mean stratum temperatures on sampling dates (Δ) usually derived from profiles at 5 or 6 stations. Ice thickness (m) indicated. Lower panel 0-2 m shallow (.....) and deep (---) zone mean water temperatures. Before noon samplings indicated as B. afternoons as A. 5 or 6 day period mean maximum and minimum air temperatures obtained from DOE weather stations in proximity of each lake	26
4a Lake 019	28
4b Lake 255	28
4c Lake 885	30
5. Secchi disc visibility (m) in the deep zone of Lakes 019, 255 and 885. April to October 1976. Means and ranges usually derived from 5 or 6 stations. Arrows (↓) indicate lake bottom visibility	34
6. Dissolved oxygen concentrations (mg O ₂ L ⁻¹) in the deep zone (0-2 m or 0-3 m layer and the bottom) of Lakes 019, 255 and 885, February 1976 to April 1977 (modified after Srisuwantach 1978)	38
7. Chlorophyll-a concentrations (μg L ⁻¹) from integrated samples over 0-2 m Lakes 019, 255 and 885, February 1976 to February 1977 (after Srisuwantach 1978)	43
8. Seasonal changes in algal and protozoan biomass (μg net weight L ⁻¹) in the deep zones of Lakes 019, 255 and 885, February 1976 to November 1976 (modified after Kling, unpublished)	45

List of Figures (Continued)

	<u>Page</u>
9. Annual mean relative abundance and biomass of cyclopoids, calanoids and cladocerans in Lakes 019, 255 and 885, April 1976 to April 1977	54
10. Annual mean crustacean zooplankton community abundance (ind L ⁻¹) and biomass (mg w w L ⁻¹) in the shallow and deep zones of Lakes 019, 255 and 885, April 1976 to April 1977. .	57
11. Annual mean abundance (ind L ⁻¹) and biomass (mg w w L ⁻¹) of cyclopoids, calanoids and cladocerans in the shallow and deep zones of Lakes 019, 255 and 885, April 1976 - April 1977	60
12. Seasonal changes in crustacean zooplankton community abundance (ind L ⁻¹) and biomass (mg w w L ⁻¹) in Lakes 019, 255 and 885, February 1976 to April 1977.	64
13. Seasonal changes in crustacean zooplankton community abundance (ind L ⁻¹) and biomass (mg w w L ⁻¹) in the shallow and deep zones of Lakes 019, 255 and 885, February 1976 to April 1977	68
14. Seasonal occurrence of crustacean zooplankton species in the shallow (white strips) and deep (black strips) zones of Lakes 019, 255 and 885, February 1976 to April 1977. Number of species per month per community total indicated at base of each lake. Sampling during ice cover period indicated by sub line markings.	71
15. Seasonal changes in the abundance (ind L ⁻¹) of core zooplankton species in the shallow and deep zones of Lake 885, February 1976 to April 1977. Lake abundance weighted on volumetric share of each zone (shallow = .15 lake volume; deep = .85 lake volume)	75
16. Seasonal changes in the biomass (mg w w .10 ⁻¹ L ⁻¹) of core zooplankton species in the shallow and deep zones of Lake 885, February 1976 to April 1977. Lake biomass weighted on volumetric share of each zone (shallow = .15 lake volume; deep = .85 lake volume)	77
17. Seasonal changes in the abundance of life history stages of <u>Cyclops bicuspidatus thomasi</u> in the shallow and deep zones of Lake 885, February 1976 to April 1977.	80
18. Seasonal changes in the abundance of life history stages of <u>Diaptomus leptopus</u> and <u>Daphnia schoedleri</u> in the shallow and deep zones of Lake 885, February 1976 to April 1977.	85
19. Comparison of composite replicate samples from the shallow and deep zones of Lake 885 on July 20 retained by a 73 μ m mesh net	88

List of Figures (continued)

20. Seasonal changes in the abundance (ind L⁻¹) of Gammarus lacustris and Chaoborus sp. in the shallow and deep zones of Lakes 019, 255 and 885, February 1976 to April 1977 . . . 93
21. Seasonal changes in the abundance (ind L⁻¹) of core cyclopoid species in the shallow and deep zones of Lake 255, February 1976 to April 1977. Lake abundance weighted on volumetric share of each zone (shallow = .20 lake volume; deep = .80 lake volume) 96
22. Seasonal changes in the biomass (mg w w .10⁻¹ L⁻¹) of core cyclopoid and calanoid species in the shallow and deep zones of Lake 255, February 1976 to April 1977 98
- 23a. Seasonal changes in the abundance (ind L⁻¹) of life history stages of core cyclopoid species in the shallow and deep zones of Lake 255, February 1976 to April 1977 100
- 23b. Seasonal changes in the abundance (ind L⁻¹) of life history stages of core cyclopoid species in the shallow and deep zones of Lake 255, February 1976 to April 1977 102
24. Seasonal changes in the abundance (ind L⁻¹) of core calanoid and cladoceran species in the shallow and deep zones of Lake 255, February 1976 to April 1977. Lake abundance weighted on volumetric share of each zone (shallow = .20 lake volume; deep = .80 lake volume) 109
25. Seasonal changes in the abundance (ind L⁻¹) of life history stages of core calanoid species in the shallow and deep zones of Lake 255, February 1976 to April 1977 112
26. Seasonal changes in the biomass (mg w w .10⁻¹ L⁻¹) of core cladoceran species in the shallow and deep zones of Lake 255, February 1976 to April 1977. Lake biomass weighted on volumetric share of each zone (shallow = .20 lake volume; deep = .80 lake volume) 117
27. Seasonal changes in the abundance (ind L⁻¹) of life history stages of core cladoceran species in the shallow and deep zones of Lake 255, February 1976 to April 1977 129
28. Seasonal changes in the abundance (ind L⁻¹) of core cyclopoid and calanoid species in the shallow and deep zones of Lake 019, February 1976 to April 1977. Lake abundance weighted on volumetric share of each zone (shallow = .06 lake volume; deep = .94 Lake volume) 125
29. Seasonal changes in the abundance (ind L⁻¹) of core cladoceran species in the shallow and deep zones of Lake 019, February 1976 to April 1977. Lake abundance weighted on volumetric

List of Figures (continued)

Page

29. share of each zone (shallow - .06 lake volume, deep = .94 lake volume) 127
30. Seasonal changes in the biomass (mg w w $10^{-1} L^{-1}$) of core cyclopoid and calanoid species in the shallow and deep zones of Lake 019, February 1976 to April 1977. Lake biomass weighted on volumetric share of each zone (shallow = .06 lake volume; deep = .94 lake volume) 132
31. Seasonal changes in the biomass (mg w w $10^{-1} L^{-1}$) of core cladoceran species in the shallow and deep zones of Lake 019, February 1976 to April 1977. Lake biomass weighted on volumetric share of each zone (shallow = .06 lake volume, deep = .94 lake volume) 134
32. Seasonal changes in the abundance (ind L^{-1}) of life history stages of core cyclopoid species in the shallow and deep zones of Lake 019, February 1976 to April 1977. For Cyclops vernalis and Eucyclops agilis only total copepodids presented 136
33. Seasonal changes in the abundance (ind L^{-1}) of life history stages of Diaptomus siciloides and Daphnia parvula in the shallow and deep zones of Lake 019, February 1976 to April 1977 140
34. Seasonal changes in the length (tip of cephalothorax to base of caudal setae, mm) and fecundity (eggs female $^{-1}$) of Cyclops bicuspidatus thomasi females in Lakes 019, 255 and 885, April 1976 to April 1977. Data points represent means of measurements of 20 randomly selected deep zone gravid females 147
35. Seasonal changes in the length (tip of cephalothorax to base of caudal setae, mm) and fecundity (eggs female $^{-1}$) of Diaptomus siciloides females in Lakes 019 (March 1976 to April 1977) and 255 (May 1976 to December 1976). Data points represent means of measurements of 20 randomly selected deep zone gravid females 149
36. Seasonal changes in the length (tip of helmet to base of shell spine, mm) of ovigerous (—) and ehippial (-----) Daphnia schoedleri and fecundity (eggs female $^{-1}$) of ovigerous Daphnia schoedleri (....) in the shallow and deep zones of Lakes 885(●) and 255 (o), May 1976 to December 1976. Data points represent means of measurements of 20 randomly selected mature females. 151
37. Seasonal changes in the length (tip of helmet to base of shell spine, mm) of ovigerous (■—■) and ehippial (■-----■) Daphnia parvula and fecundity (eggs female $^{-1}$) of ovigerous Daphnia parvula females in the deep zone of Lake 019, February 1976 to December 1976. Data points represent means of measurements of 20 randomly selected mature females. 154

List of Figures (continued)

Page

38. Five parameters of the three study lakes compared with other North American lakes. Ranges (\longleftrightarrow) and/or means ($\text{---}\bullet\text{---}$; \bullet) of midsummer values presented; epilimnion values used for chemical parameters. ELA stands for Experimental Lakes Area, northwestern Ontario. Dotted vertical lines represent approximate trophic boundaries from Dobson et al. (1974) (modified after Archibald 1977). . . 162

LIST OF APPENDICES

<u>Appendix</u>	<u>Page</u>
A Secchi disc visibility (m) at shallow and deep zone stations of Lake 019 during the open water seasons of 1976 and 1977. Zone means on each date, deep zone station means during the period 28.6 to 24.9 and shallow zone station means during the period 28.6 to 9.9 provided	201
B Secchi disc visibility (m) at shallow and deep zone stations of Lake 255 during the open water seasons of 1976 and 1977. Readings to lake bottom indicated as B. Zone means on each date provided	202
C. Secchi disc visibility (m) at shallow and deep zone stations of Lake 885 during the open water seasons of 1976 and 1977. Readings to lake bottom indicated as B. Zone means on each date and deep zone station means during the period 6.7 to 23.9 provided	203
D Precipitation (mm) receipts in the vicinities of Lakes 019 (Minnedosa AES station), 255 (Wasagaming AEC station) and 885 (Strathclair AES station) during the period February to December 1976. Data from Environment Canada 1976	204
E. Seasonal distribution of the major groups of phytoplankton in Lakes 019, 255 and 885, February 1976 to February 1977 (after Srisuwantach 1978)	205
F Seasonal abundance (ind L ⁻¹) of the life history stages of crustacean zooplankton species in the shallow ($z \leq 1.5$ m) zone of Lake 019, April 1976 to April 1977. Numbers represent means of counts of two composite samples each consisting of 6 subsamples taken in the shallow zone. Weighted shallow total abundance obtained from community totals (excluding harpacticoids, chaoborids and gammarids) x .06 (shallow zone share of lake volume). For copepods: ♀ = exovigerous adult females; ♀ _{ov} = ovigerous females; ♂ = adult males; CIV-V = copepodid stages IV and V (or older immatures); CI-III = copepodid stages I and II and III (or younger immatures). For cladocerans: ♀ = exovigerous adult females; ♀ _{ov} = ovigerous females; ♀ _{eph} = ehippial females; ♂ = total males	206
G Seasonal biomass (mg wet weight L ⁻¹) of the life history stages of crustacean zooplankton species in the shallow ($z \leq 1.5$ m) zone of Lake 019, April 1976 to April 1977. Biomass values from corresponding abundances and cold (<20°) or warm (>20°) period mean lengths converted to weight using formulae of Klekowski and Shushkina (1966) (in Edmondson 1971). Total numbers and biomass generated during cold, warm or entire study periods presented at right. Other explanations as in Appendix F	207

Appendices (continued)

Page

H	Seasonal abundance (ind L ⁻¹) of the life history stages of crustacean zooplankton species in the deep (z >1.5 m) zone of Lake 019, February 1976 to April 1977. Numbers represent means of counts of two composite samples each consisting of 6 subsamples taken in the deep zone. Weighted deep total abundance obtained from community totals (excluding harpacticoids, chaoborids and gammarids) x .94 (deep zone share of lake volume). Other explanations as in Appendix F	208
I	Seasonal biomass (mg wet weight L ⁻¹) of the life history stages of crustacean zooplankton species in the deep (z >1.5m) zone of Lake 019, February 1976 to April 1977. Other explanations as in Appendices G and H.	209
J	Seasonal abundance (ind L ⁻¹) of the life history stages of crustacean zooplankton species in the shallow (z ≤1.5m) zone of Lake 255, April 1976 to April 1977. Numbers represent means of counts of two composite samples each consisting of 5 subsamples taken in the shallow zone. Weighted shallow total abundance obtained from community totals (excluding harpacticoids, chaoborids, and gammarids) x .20 (shallow zone share of lake volume). Other explanations as in Appendix F.	210
K	Seasonal biomass (mg wet weight L ⁻¹) of the life history stages of crustacean zooplankton species in the shallow (≤1.5 m) zone of Lake 255, April 1976 to April 1977. Other explanations as in Appendix G and J.	211
L	Seasonal abundance (ind L ⁻¹) of the life history stages of crustacean zooplankton species in the deep (z >1.5m) zone of Lake 255, February 1976 to April 1977. Numbers represent means of counts of two composite samples each consisting of 5 subsamples taken in the deep zone. Weighted deep total abundance obtained from community totals (excluding harpacticoids, chaoborids, and gammarids) x .80 (deep zone of lake volume). Other explanations as in Appendix F.	212
M	Seasonal biomass (mg wet weight L ⁻¹) of the life history stages of crustacean zooplankton species in the deep (z >1.5m) zone of Lake 255, February 1976 to April 1977. Other explanations as in Appendices G and L	213
N	Seasonal abundance (ind L ⁻¹) of the life history stages of crustacean zooplankton species in the shallow (z <1.5m) zone of Lake 885, April 1976 to April 1977. Numbers represent means of counts of two composite samples each consisting of 5 subsamples taken in the shallow zone. Weighted shallow total abundance obtained from community totals (excluding harpacticoids, chaoborids and gammarids) x .15 (shallow zone share of lake volume). Other explanations as in Appendix F. . .	214

	<u>Page</u>
O Seasonal biomass (mg wet weight L^{-1}) of the life history stages of crustacean zooplankton species in the shallow ($z \leq 1.5m$) zone of Lake 885, April 1976 to April 1977. Other explanations as in Appendices G and N	215
P Seasonal abundance (ind L^{-1}) of the life history stages of crustacean zooplankton species in the deep ($z > 1.5m$) zone of Lake 885, February 1976 to April 1977. Numbers represent means of counts of two composite samples each consisting of 5 subsamples taken in the deep zone. Weighted deep total abundance obtained from community totals (excluding harpacticoids, chaoborids and gammarids) x .85 (deep zone share of lake volume). Other explanations as in Appendix F	216
Q Seasonal biomass (mg wet weight L^{-1}) of the life history stages of crustacean zooplankton species in the deep ($z > 1.5m$) zone of Lake 885, February 1976 to April 1977. Other explanations as in Appendices G and P	217
R Season mean total egg and ephippia abundance (eggs L^{-1}) for the major zooplankton species in the shallow and deep zones of Lake 885, February 1976 to April 1977. Mean fecundities (egg clutch $^{-1}$) determined from egg counts of 20 ovigerous females on each sampling date. <div style="margin-left: 2em;"> <p>○ = ovigerous females</p> <p>● = ephippial cladocerans</p> </div>	218
S Seasonal mean total egg and ephippia abundance (eggs L^{-1}) for the major zooplankton species in the shallow and deep zones of Lake 255, February 1976 to April 1977. Other explanations as in Appendix R	219
T Seasonal mean total egg and ephippia abundance (eggs L^{-1}) for the major zooplankton species in the shallow and deep zones of Lake 019, February 1976 to April 1977. Other explanations as in Appendix R	220
U Weighted mean abundance (ind L^{-1}) and biomass (mg wet weight L^{-1}) of the major taxonomic groups in Lakes 019, 255 and 885 during various seasons of the annual cycle. S/A = seasonal to annual (April 1976 to April 1977) mean total community abundance and biomass ratios.	221
V Seasonal changes in the relative importance of major food organisms (wet weight) identified in trout stomachs. The number of stomachs examined and the number of empty stomachs in parenthesis is indicated on the top of each bar (after Tavarutmaneegul 1978)	222

INTRODUCTION

The understanding of crustacean zooplankton ecology in western Canada has grown appreciably over the past 50 years. To a large extent, the evolution of this knowledge was governed by the size, remoteness and the economic development of this region. Early studies by Baikov (1930, 1934), Rawson (1947, 1960) and Reed (1964) among others concentrated primarily on documenting fundamental limnological data from some of the more prominent lakes in the west.

As investigations continued, post glacial dispersion patterns of crustacean species were also considered. Studies by Carl (1940) and Anderson (1974) on montaine lakes in British Columbia, the saline lakes of Saskatchewan by Rawson and Moore (1944) and Moore (1952), on North American daphnids by Brooks (1957), large North American lakes by Patalas (1975), the Yukon lakes by Archibald (1977) have contributed towards our understanding of this process.

To complement this fundamental research, more effort is now being directed towards examining the temporal and spatial variability of zooplankton communities as well as the environmental and biotic factors governing plankton dynamics. Because of technical difficulties involved in remote sampling, the earlier works were usually restricted to a single sampling period in mid-summer or to one limnetic station. In the past, this approach was adequate for classifying lacustrine productivity and trophic status (Larkin and Northcote 1958, Rawson 1961). Today, when the environmental impacts of toxins, petroleums, acids, radioactive wastes and other contaminants associated with cultural eutrophication need to be accurately assessed, a clear idea of "natural" community and population

fluctuations is an important prerequisite. Likewise, the horizontal variation of plankton distributions within lakes needs quantitative refinement. Information is available for larger eastern Canadian lakes (Langford 1938; Davis 1966; Rigler and Langford 1967; Schindler and Noven 1971; Patalas 1969, 1971, 1972; Davis 1973; Watson and Carpenter 1974; Clark and Carter 1974; McNaught and Buzzard 1974) but few studies have been undertaken in the west (Bajkov 1929; Hammer and Sawchyn 1968; Anderson 1970; Donald 1971; Lei and Clifford 1974; Herzig et al. 1980). Although comparison with other data is instructive, the high degree of crustacean community variability recorded throughout the literature (Hutchinson 1967) impresses the need of further regional sampling. As Schindler (1978) points out, more complete data are still needed for many areas.

Prairie pothole lakes are characteristically shallow, nutrient rich and often covered with aesthetically unappealing algal scums, perhaps the reason for their lack of attention. As a result of their physicochemical properties, many are impacted by catastrophic "summer or winterkills", periods of low ($< 1.0 \text{ mg O}_2 \text{ L}^{-1}$) oxygen concentration which are often fatal to resident fish but allow for development of extremely dense invertebrate populations. This invertebrate resource currently supports rainbow trout aquaculture in the Erickson-Elphinstone area of western Manitoba. Several lakes in the district, because of their relatively larger size, do not exhibit periods of complete anoxia and consequently support perennial fish populations. This combination of "kill and non-kill" lakes provided a unique opportunity to examine the effects of anoxia on crustacean zooplankton development as well as to compare zooplankton community structure, seasonal dynamics and trophic interrelationships within three lakes 019, 255, and 885. Differences between the plankton of deeper, central and shallower, nearshore zones of each lake were also considered. Winter

sampling formed a significant part of the study since data on planktonic growth during the ice cover period are relatively scarce.

This research was conducted as one part of a joint program involving the efforts of V. Srisuwantach (1978) - nutrients and phytoplankton, P. Tavarutmaneegul (1978) - rainbow trout production and J. Boonsom, zooplankton-fish interactions. The study, supported by the Freshwater Institute, provided for a comprehensive analysis of the prairie pothole ecosystem. Perhaps it can be considered a forerunner of the cooperative thesis concept advocated by Vallentyne (1974).

THE LAKES

Lakes 885, 255 and 019 are located in west central Manitoba near the town of Erickson, positioned at $50^{\circ}30'N$ and $99^{\circ}55'W$, approximately 330 km northwest of Winnipeg (Fig. 1). The study area lies on the Manitoba Escarpment which rises between 460 and 760 meters above the lowland plains of central Manitoba at 450 m a.s.l. Morrainal deposits characterizing the region were remnants of the final, Wisconsin stage of Pleistocene glaciation. With the retreat of Lake Agassiz, hundreds of small, shallow ponds and lakes remained which ultimately became domestic and livestock watering sources for many farms developing in the area. Lake 019 currently receives drainage from a barnyard and farmhouse on its northern shore while lake 885 is situated on an abandoned farmstead (Figs. 2a,c). Both lakes are largely surrounded by trees and are adjoined by grainfields of predominantly grey wooded or fertile black soils. Lake 255 (Fig. 2b), situated between a railroad track and a provincial highway, is comparatively removed from direct agricultural influence although a cultivated field exists a short distance to the east.

Figure 1. The location of Lakes 019, 255 and 885 in the Erickson-Elphinstone, Manitoba study area.

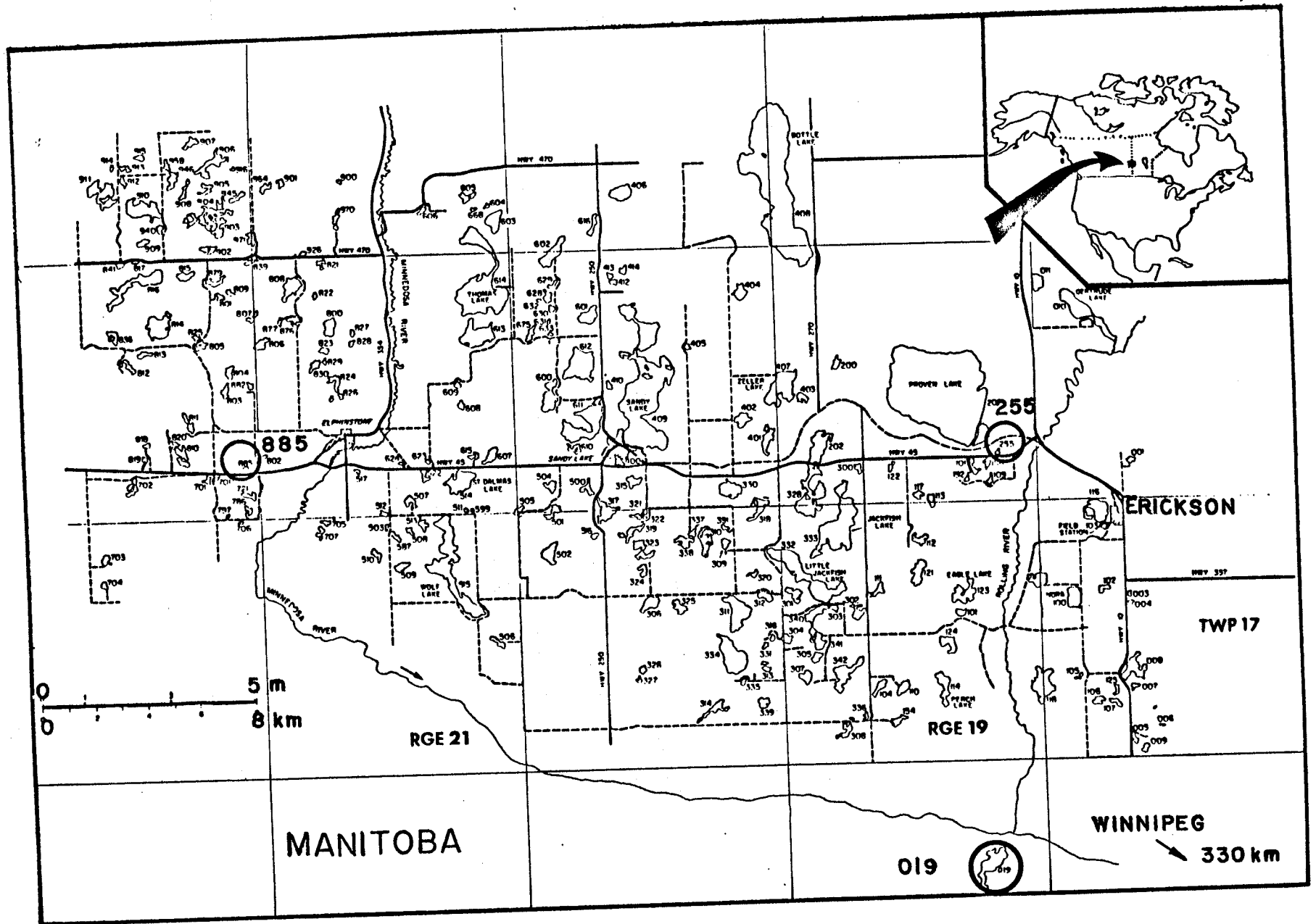


Figure 2a. Bathymetric map of Lake 019 (contours in meters) showing the distribution of shallow(s) and deep (D) zone sampling stations each with a pair of sub-sampling sites (o and ● or □ and ■). Subsamples from similarly designated sites within each zone combined, resulting in two composite samples from each zone. Extent of emergent macrophytes..... and borderline of trees and cultivated fields----- also indicated. Trees, farm buildings and roadways approximately to scale.